

## VI. INVERTEBRATE DRIFT IN THE LOWER SUSQUEHANNA RIVER BELOW CONOWINGO DAM

### A. INTRODUCTION

Benthic invertebrate communities below hydroelectric projects respond to fluctuations in flow in a variety of ways. One of the more obvious and widely studied responses has been invertebrate drift. Armitage (1977) observed that nighttime peaks in the number of drifting organisms were less pronounced in a regulated river than in unregulated rivers. Armitage and Capper (1976) found that discharge of microcrustaceans from the reservoir upstream of a dam greatly influenced the composition and abundance of downstream drift. Microcrustaceans can be a major food source for both filtering benthic invertebrates, such as trichopterans, and fishes in the river downstream of dams.

In unregulated streams and rivers, large fluctuations in flow can greatly affect invertebrate drift. For example, Pearson and Franklin (1968) showed that catastrophic drift of mayflies and blackflies resulted from sudden flow increases. Reduced flows can also result in large increases in drift, with virtually all organisms being affected (Corrarino and Brusven 1983, Minshall and Winger 1968). Hughes (1970) has also observed increased drift of Gammarus pulex at low flows.

At peaking hydroelectric facilities, large fluctuations in flow over very short periods (hours) are common. It seems likely that these large fluctuations will strongly influence the downstream invertebrate drift.

The objective of this study was to examine the relationship between discharge from Conowingo Dam and invertebrate drift in the lower Susquehanna River. This relationship is important to understanding how variation in turbine operations affects the fishes in the Conowingo vicinity, because drift can provide a major food source for these fishes (Elliot 1973, Allan 1981).

### B. METHODS

Benthic drift was sampled in 1983 concomitantly with the fish collections, described in Chapter III, by use of stationary nets. Table VI-1 gives the sampling dates and times. Each net had a rectangular opening of 46 by 25 cm, was 4.25 m long, and was constructed of 500  $\mu$ m mesh Nitex. Four nets could

Table VI-1. Sampling dates and times for the 1983 invertebrate drift study.

Date	Time (DST)	Date	Time (DST)
16 August	1100	15 September	0200
	1400		0500
	1700		
	2000	28 September	0800
	2300		1100
			1400
17 August	0200		1700
	0500		2000
	0800		2300
14 September	0800	29 September	0200
	1100		0500
	1400		
	1700	10 October	0800
	2000		1100
	2300		1400
			1700
			2000
			2300
		11 October	0200
			0500

be mounted on each of two metal frames anchored in the river channel at Transect D. Each frame was 2.5 m high. Nets were set before sampling for fish and were submerged for 1-3 hours, depending on river flow. Nets were deployed on both frames at every level at which it was deep enough to submerge a net entirely. Flow through each net was monitored with a General Oceanics current meter, deployed in the center of the net. Wet time for each net was also recorded. After collection, net contents were washed into plastic sample bottles and preserved in 10% formalin.

Zooplankton were collected every 3 hours with a 20-cm diameter, 202- $\mu$ m mesh plankton net. Two replicate samples were taken by vertical hauls from the river bottom. Approximately 0.5-1.0 m<sup>3</sup> of water was filtered for each sample. Actual volume filtered was measured with a General Oceanics current meter placed in the center of the net. Contents from the samples were washed into 0.5-liter containers and preserved in 10% formalin.

Laboratory analysis of the drift samples included sorting, identification to the lowest practical taxonomic level, and determination of the number of organisms/sample.

River flow data were obtained from the USGS.

Catch per unit effort (CPUE) values were calculated by dividing the total number of organisms per sample by the sampling time. This calculation was made for two reasons. First, volume filtered estimates based on flow meter readings were extremely variable (up to three orders of magnitude), especially at high river flows. Therefore, volumetric estimates of drift density were of little value. Second, the intent of obtaining the drift samples was to compare the numbers and types of drifting organisms to the stomach contents of fishes collected simultaneously. The CPUE can be very informative with respect to fish feeding, since it expresses the number of drifting organisms passing a plane in the water column per unit time. For "sit and wait" predators, CPUE represents the number of potential prey that pass per unit time. On the other hand, if the fishes being investigated were filter feeders, then the CPUE metric would be of little value, and volume filtered estimates would be required.

### C. RESULTS

Table VI-2 presents the mean CPUE and percentage contribution to the total CPUE for the most commonly observed taxa. In all, 53 taxa were collected in the stationary drift net samples. Eight taxa made up 97.5% of the total CPUE. Leptodora kindtii,

Table VI-2. Mean catch per unit effort (CPUE) and cumulative contribution to total CPUE for the most commonly observed taxa in the drift samples in 1983.

Taxon	Mean CPUE (No./hr)	Cumulative Contribution Total CPUE (%)
<u>Leptodora kindtii</u>	661	74.4
<u>Chaoborus</u> larvae	48	79.7
Oligochaetes	38	83.9
Chironomid pupae	36	87.7
<u>Manayunkia speciosa</u>	32	91.3
Chironomid larvae	24	94.0
<u>Chaoborus</u> pupae	17	95.9
<u>Cheumatopsyche</u> larvae	14	97.5*

\* The remaining 2.5% of the total CPUE consisted of 45 taxa.

a large predacious cladoceran, dominated the stationary drift net collections and accounted for nearly 75% of the total CPUE. This organism is primarily lacustrine, and its major source in this study area is Conowingo Pond. The reservoir also provides the source of Chaoborus larvae and pupae; reservoir-originating organisms make a total contribution of 81.7% to the total CPUE. The major drift organisms that originated from the river bottom below Conowingo Dam include oligochaetes, Manayunkia speciosa, chironomid larvae, and Cheumatopsyche larvae (Table VI-2).

Table VI-3 presents the mean CPUE for Leptodora kindtii for each sampling period on each date. On 16-17 August, the CPUE was relatively constant from 1400 through 0500, with somewhat lower values at 0800 and 1100. Thus, there was little response to the changing flow, except that the increase in the CPUE coincided with the increase in flow at 1400. On 14-15 September, there was a midday decline in CPUE for Leptodora, with little variation among the other sampling periods. On the two sampling dates in which no minimum flow was maintained (28-29 September and 10-11 October) there was a marked response in Leptodora CPUE to increases in flow. At 1100 on both days, large increases in flow coincided with large increases in CPUE. On 28 September, the increased flows continued through the 1400 sampling period, and the CPUE also remained at high levels. After both periods of high flow, the CPUE declined rapidly.

Table VI-4 the mean CPUE for Chaoborus larvae. Chaoborus larvae displayed a rather distinct diel drift pattern. In general, the Chaoborus CPUE was greater at night, regardless of the amount of flow. There were, however, some exceptions. For example, on 16 August at 1400 and on 28 September at 1100, large increases in CPUE coincided with large increases in flow.

The drift behavior of oligochaetes exhibited a marked response to large increases in flow (Table VI-5), as well as a diel temporal pattern. The diel pattern was most apparent on 14-15 September, when flow was relatively constant; CPUE values peaked at 0200, 0500, and 0800. On 16-17 August and especially on 28-29 September, the highest CPUE values for oligochaetes coincided with the highest flows.

For the most part, chironomid larvae and pupae (Tables VI-6 and VI-7) responded to changes in flow similarly to oligochaetes. On the first two sampling dates, when the minimum flow was maintained, chironomid larvae and pupae CPUE values generally were highest at night, but positive responses to the peak flow of about 28,000 cfs at 1400 on 16 August were also observed. On the two dates with no minimum flow, the drift of both the

Table VI-3. Mean CPUE for Leptodora kindtii by sampling date and time (n = 2) and mean flow for each sampling period

Time	Mean CPUE (No./hr)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	--	57	55.7	61.4
1100	63.8	19	4074.7	269.4
1400	170.8	1.2	5634.8	6.4
1700	114.9	1.0	689.8	2.4
2000	134.7	26.1	463.5	2.9
2300	173.0	25.5	109.5	2.4
0200	124.1	28.9	33.7	0.8
0500	183.8	32.5	25.5	0.5
0800	87.0	--	--	--

Time	Mean Flow (cfs)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	--	5147	6498	2259
1100	5147	5122	36248	6910
1400	28855	5198	37738	1050
1700	5449	5198	4461	886
2000	5198	5248	4911	874
2300	5122	5273	1030	899
0200	5147	5298	930	904
0500	5147	5424	902	928
0800	5248	--	--	--

Table VI-4. Mean CPUE for Chaoborus larvae by sampling date and time and mean flow for each sampling period. Sample size = 2 in each case.

Time	Mean CPUE (No./hr)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	--	0	0.5	3.8
1100	0	0	60.5	2.6
1400	41.7	0.6	3.9	0.2
1700	2.1	0	5.8	0.2
2000	46.1	51.3	141.1	2.2
2300	25.5	131.4	43.9	10.0
0200	16.5	144.5	1.4	10.3
0500	10.9	66.0	6.4	2.8
0800	0	--	--	--

Time	Mean Flow (cfs)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	--	5147	6498	2259
1100	5147	5122	36248	6910
1400	28855	5198	37738	1050
1700	5449	5198	4461	886
2000	5198	5248	4911	874
2300	5122	5273	1030	899
0200	5147	5298	930	904
0500	5147	5424	902	928
0800	5248	--	--	--

Table VI-5. Mean CPUE for oligochaetes by sampling date and time and mean flow for each sampling period. Sample size = 2 in each case.

Time	Mean CPUE (No./hr)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	--	63.2	2.7	4.9
1100	18.4	15.0	329.9	1.1
1400	24.5	2.3	7.8	0.6
1700	96.0	11.0	0.5	0
2000	3.8	21.0	1.5	0
2300	2.5	13.8	0.5	0
0200	1.6	61.9	0	0
0500	2.7	69.0	0	1.0
0800	9.4	--	--	--

Time	Mean Flow (cfs)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	-	5147	6498	2259
1100	5147	5122	36248	6910
1400	28855	5198	37738	1050
1700	5449	5198	4461	886
2000	5198	5248	4911	874
2300	5122	5273	1030	899
0200	5147	5298	930	904
0500	5147	5424	902	928
0800	5248	--	--	--

Table VI-6. Mean CPUE for chironomid larvae by sampling date and time and mean flow for each sampling period. Sample size = 2 in each case.

Time	Mean CPUE (No./hr)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	--	48.5	0.5	8.7
1100	46.3	28.2	29.2	0.7
1400	201.2	15.6	3.9	0.6
1700	17.9	10.0	0	1.1
2000	22.7	11.3	2.69	0
2300	17.4	17.1	0.5	0
0200	9.5	55.3	0.3	0.5
0500	18.7	58.5	2.32	0.5
0800	18.6	--	--	--

Time	Mean Flow (cfs)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	--	5147	6498	2259
1100	5147	5122	36248	6910
1400	28855	5198	37738	1050
1700	5449	5198	4461	886
2000	5198	5248	4911	874
2300	5122	5273	1030	899
0200	5147	5298	930	904
0500	5147	5424	902	928
0800	5248	--	--	--

Table VI-7. Mean CPUE for chironomid pupae by sampling date and time and mean flow for each sampling period. Sample size = 2 in each case.

Time	Mean CPUE (No./hr)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	--	25.5	0.5	10.6
1100	12.9	10.6	29.0	0
1400	29.3	4.0	1.3	1.0
1700	29.0	0.5	1.1	5.4
2000	123.9	14.5	6.8	1.8
2300	91.0	18.5	4.6	1.0
0200	61.0	77.4	2.7	1.0
0500	37.9	168.0	3.3	2.0
0800	9.8	--	--	--

Time	Mean Flow (cfs)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	--	5147	6498	2259
1100	5147	5122	36248	6910
1400	28855	5198	37738	1050
1700	5449	5198	4461	886
2000	5198	5248	4911	874
2300	5122	5273	1030	899
0200	5147	5298	930	904
0500	5147	5424	902	928
0800	5248	--	--	--

larvae and pupae was extremely low, except at the 1100 sampling period on 28 September, when flow exceeded 35,000 cfs. At that time, large increases in the numbers of chironomid larvae and pupae were observed in the drift.

Cheumatopsyche larvae were clearly most abundant in the drift on 16 August (Table VI-8). On this date, the larvae responded to the peak flow at 1400, with nearly a threefold increase in CPUE. This response was much less, however, than the peak CPUE values observed at night. On 14 September, when flow was relatively constant, the CPUE also increased at night, but to a much lesser extent. The CPUEs for Cheumatopsyche larvae were very low on the last two sampling dates.

The polychaete Manayunkia was relatively abundant in the drift samples collected at high flows (Table VI-9), most notably on 16 August at 1400 and on 28 September at 1100. There was some suggestion of a diel drift pattern of higher CPUE at night on the first two sampling dates. On the last two sampling dates, the CPUE for Manayunkia was extremely low, except at 1100 on 28 September, when the large increase in flow apparently resulted in a large increase in the number of Manayunkia.

The abundance of cladocerans observed below Conowingo Dam did not show either a diel pattern or a response to changes in flow (Table VI-10). Copepod abundance, however, was clearly affected by flow conditions on the last two sampling dates (Table VI-11), when copepods were much more abundant at high flows than at flows <1,000 cfs.

#### D. DISCUSSION

The results of this study suggest that the invertebrate drift in the lower Susquehanna River depends upon flow through Conowingo Dam. Conowingo Pond was the source of three taxa that were major components of the drift. The abundance of Leptodora, a large predacious cladoceran that is primarily lacustrine in nature (Hutchinson 1967), did not vary appreciably when the 5,000-cfs minimum flow was maintained. There was a marked decline in Leptodora CPUE, however, when flows were low. Chaoborus larvae and pupae also likely originated from Conowingo Pond, since they were never found in the benthic samples collected below the dam (Chapter II). During the day, the larvae of this dipteran are found primarily in the sediments, and at night, they migrate vertically into the overlying water column, where they feed and pupate (Jonasson 1972). The data collected in this study suggest that only at night is Chaoborus susceptible to being entrained in the dam discharge, because it was much more abundant in night drift collections, regardless of flow conditions.

Table VI-8. Mean CPUE for Cheumatopsyche larvae by sampling date and time and mean flow for each sampling period. Sample size = 2 in each case.

Time	Mean CPUE (No./hr)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	--	3.4	0	0.5
1100	4.7	1.9	3.6	0.4
1400	11.2	0.6	0	0
1700	3.0	0	0	0.2
2000	68.2	2.1	0	0.4
2300	92.4	0.8	0.5	0
0200	91.5	8.2	0	0
0500	45.0	5.0	0.5	0.3
0800	10.8	--	--	--

Time	Mean Flow (cfs)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	--	5147	6498	2259
1100	5147	5122	36248	6910
1400	28855	5198	37738	1050
1700	5449	5198	4461	886
2000	5198	5248	4911	874
2300	5122	5273	1030	899
0200	5147	5298	930	904
0500	5147	5424	902	928
0800	5248	--	--	--

Table VI-9. Mean CPUE for Manayunkia speciosa by sampling date and time and mean flow for each sampling period. Sample size = 2 in each case.

Time	Mean CPUE (No./hr)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	--	19.4	0.5	5.7
1100	52.6	7.1	603.0	0.7
1400	116.5	0.6	3.9	0
1700	14.1	3.0	0.5	0.2
2000	19.2	2.1	1.2	0
2300	23.2	2.9	0	0
0200	4.2	7.8	0	0
0500	35.6	17.0	0.2	0
0800	23.0	--	--	--

Time	Mean Flow (cfs)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	--	5147	6498	2259
1100	5147	5122	36248	6910
1400	28855	5198	37738	1050
1700	5449	5198	4461	886
2000	5198	5248	4911	874
2300	5122	5273	1030	899
0200	5147	5298	930	904
0500	5147	5424	902	928
0800	5248	--	--	--

Table VI-10. Mean CPUE for cladocerans by sampling date and time and mean flow for each sampling period. Sample size = 2 in each case.

Time	Mean CPUE (No./hr)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	--	6,627	2,960	7,638
1100	2,503	6,109	2,297	5,443
1400	3,572	9,031	4,065	4,022
1700	3,621	5,454	6,356	7,219
2000	3,335	10,117	4,148	6,408
2300	1,746	9,908	4,911	3,522
0200	5,573	11,824	2,085	3,554
0500	7,260	6,608	3,623	2,796
0800	4,022	--	--	--

Time	Mean Flow (cfs)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	--	5147	6498	2259
1100	5147	5122	36248	6910
1400	28855	5198	37738	1050
1700	5449	5198	4461	886
2000	5198	5248	4911	874
2300	5122	5273	1030	899
0200	5147	5298	930	904
0500	5147	5424	902	928
0800	5248	--	--	--

Table VI-11. Mean CPUE for copepods by sampling date and time and mean flow for each sampling period. Sample size = 2 in each case.

Time	Mean CPUE (No./hr)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	--	4,069	6,754	20,669
1100	1,440	4,908	11,864	17,386
1400	4,443	6,335	15,203	11,802
1700	3,370	5,871	12,135	9,015
2000	2,402	8,529	10,588	6,408
2300	1,000	7,936	5,346	4,512
0200	1,628	3,522	2,053	5,949
0500	3,250	2,059	1,834	5,970
0800	3,966	--	--	--

Time	Mean Flow (cfs)			
	16-17 Aug.	14-15 Sept.	28-29 Sept.	10-11 Oct.
0800	--	5147	6498	2259
1100	5147	5122	36248	6910
1400	28855	5198	37738	1050
1700	5449	5198	4461	886
2000	5198	5248	4911	874
2300	5122	5273	1030	899
0200	5147	5298	930	904
0500	5147	5424	902	928
0800	5248	--	--	--

The drift behavior of organisms that were components of the downstream benthic invertebrate community also was affected by the turbine operations at Conowingo Dam. Oligochaetes exhibited a diel pattern in drift abundance. Generally, when the 5,000-cfs minimum flow was maintained, more oligochaetes were observed at night. On the sampling dates when minimum flow was not maintained, there were large reductions in the number of oligochaetes observed in the night drift samples collected at flows <1,000 cfs. Therefore, given relatively constant flow, such as was observed on 14 September, the drift behavior of oligochaetes is primarily diel and relatively unaffected by flow.

Two important organisms in the benthic community of the lower Susquehanna River, chironomid larvae and pupae and Cheumatopsyche larvae, showed increased abundance in the drift samples collected at night. They also showed small responses to the variation in flow observed on the first two sampling dates. At flows <1,000 cfs, there were very few Cheumatopsyche or chironomids observed in the drift.

The results for zooplankton were varied: cladocerans showed little response to changes in flow, while copepods were much less abundant when flows were <1,000 cfs.

The main conclusion that can be drawn from these data is that most taxa exhibited typical diel periodicity in drift behavior when flows were relatively constant. Reductions in flow to levels less than 5,000 cfs, however, apparently disrupted this pattern and resulted in extremely low drift, even at night. There also were obvious increases in drift at high flows for most taxa. It may be suggested that this relationship was an artifact of the sampling method. If the drift estimates depended strictly on flow, however, then proportional changes in flow and drift would be approximately the same. This was not the case for any of the periods of peak discharge from Conowingo Dam.

## VII. CONCLUSIONS

Stomach contents of white perch, yellow perch, and channel catfish collected before and after institution of a 5,000-cfs minimum flow from Conowingo Dam were compared to determine whether feeding by fish was affected by the minimum flow (Chapter V). Prey was considerably more abundant in the stomachs of all three fish species in the years (1982 and 1983) in which a minimum flow was maintained. Two taxa, trichopterans and chironomids, were an order of magnitude more abundant in the stomachs of all fish species in the years following institution of a minimum flow. Chaoborus, cladocerans, and copepods were also taken in much greater numbers in 1982 and 1983 than in 1980, but these prey constituted only a small part of the diet biomass for channel catfish and yellow perch in all years. There was little effect of a minimum flow on the abundance of several other prey taxa, particularly Gammarus and gastropods, in the fish stomachs.

Although prey consumption by fish showed some response to instantaneous flow conditions, our studies indicate that the differences in consumption in 1980 vs 1982 and 1983 could not be attributed to short-term behavioral responses by fish to lack of continuous flow in 1980 (Chapter IV). Channel catfish showed a tendency towards greater feeding when river flow was 5,000 cfs than when it was less than 1,000 cfs, but this difference was considerably less than the between-year differences and was not mirrored in the other fish species. Diet composition of all fish species varied with flow conditions, but these changes were less than the between-year differences in diet.

It is more likely that the differences in feeding before and after institution of a minimum flow are directly attributable to concomitant changes in the abundance of prey species. The effects of the 5,000-cfs minimum flow on benthic invertebrates was measured in three ways (Chapter II): 1) by their abundance in basket samplers in 1980 vs 1982; 2) by their densities before and after cessation of minimum flow on September 15 in 1982 and 1983; 3) and by their relative densities in channel and exposed areas habitat before and after cessation of minimum flow in 1982 and 1983. The conclusions about the effect of the minimum flow were the same, regardless of which method was used. Population sizes of chironomids and Cheumatopsyche were drastically lower in the absence of a sustained minimum flow. Consumption of these invertebrate species by fish was more than an order of magnitude greater in the years with a sustained minimum flow. Other prey taxa, such as Gammarus and gastropods, showed little response in abundance to the minimum flow, and consumption of these species by fish was relatively unchanged from before to after institution of the minimum flow.

The increased prey consumption by fish in years with a sustained minimum in flow led to an increase in the condition factor, and presumably growth rate, of all three fish species (Chapter V). Although it is not certain that higher consumption increases population size, a higher condition factor is usually associated with increased fecundity (Weatherley 1972). Greater abundance of food may also increase the immigration of fish from other areas (Slaney and Northcote 1974). Other studies have suggested that population size of riverine fishes is correlated with abundance of available prey (Mason 1976, Gibson and Galbraith 1975, Walburg et al. 1971). If so, the higher condition factors we observed in 1983 indicate the likelihood that population size of Susquehanna River fish is related to population size of their prey.

The purpose of this study was to gather information that will assist resource agencies in determining "minimum flow releases which are necessary to protect and enhance fish and wildlife resources." The results of the fish study suggest that feeding behavior is not detrimentally affected by low flows, but that the amount of food consumed is reduced because of the negative effects of low flows on the size of their prey populations. Management of a forage base is an accepted practice for piscivorous fish, particularly in estuarine and lacustrine environments. Such management efforts have been suggested as an option for riverine fisheries (Campbell 1979), but are not widely practiced in that environment. While it is important that a minimum flow requirement provide suitable physical habitat for fish, this study suggests that any future decision about minimum flow should also account for the instream flow needs of fish prey, particularly benthic invertebrates.

VIII. REFERENCES

- Abdurakhmanov, Y.A. 1960. The effect of regulation of the flow of the Kura River on the behavior and abundance of fishes in the region below the Mongecharu hydroelectric station. Fisheries Res. Bd. Can. transl. ser. 258:1-4.
- Allan, J.D. 1978. Trout predation and the size composition of drift. Limnol. Oceanogr. 23:1231-1237.
- Allan, J.D. 1981. Determinants of diet of brook trout (Salvelinus fontinalis) in a mountain stream. Can J. Fish Aquat. Sci. 30:184-192.
- Allen, K.O. 1974. Effects of stocking density and water exchange rate on growth and survival of channel catfish Ictalurus punctatus (Rafinesque) in circular tanks. Aquaculture 4:29-40.
- Andrews, J.W., T. Murai and G. Gibbons. 1973. The influence of dissolved oxygen on the growth of channel catfish. Trans. Am. Fish. Soc. 102:835-838.
- Armitage, P.D. 1976. A quantitative study of the invertebrate fauna of the River Tees below Cow Green Reservoir. Freshwater Biol. 6:229-240.
- Armitage, P.D. 1978. Downstream changes in the composition, numbers and biomass of bottom fauna in the Tees below Cow Green Reservoir and in an unregulated tributary Maize Beck, in the first five years after impoundment. Hydrobiologia 58:145-156.
- Armitage, P.D. 1977. Invertebrate drift in the regulated River Tees and an unregulated tributary Maize Beck, below Cow Green dam. Freshwater Biol. 7:167-183.
- Armitage, P.D., and Capper, M.H. 1976. The numbers, biomass and transport downstream of microcrustaceans and Hydra from Cow Green Reservoir (Upper Teesdale). Freshwater Biol. 6:425-432.
- Bailey, R.M., and H.M. Harrison, Jr. 1945. Food habits of the southern channel catfish (Ictalurus lacustris punctatus) in the Des Moines River, Iowa. Trans. Am. Fish. Soc. 75:110-138.

- Brett, J.R. 1979. Environmental factors and growth. in: Fish Physiology. Hoar, W.S., D.J. Randall and J.R. Brett, eds. Volume VIII. Bioenergetics and Growth, pp. 599-675. New York: Academic Press.
- Brooker, M.P. and R.J. Hemsworth. 1978. The effect of the release of an artificial discharge of water on invertebrate drift in the R. Wye, Wales. *Hydrobiologia* 59:155-163.
- Brooks, M.J., R.O. Smitherman, J.A. Chappell, and R.A. Dunham. 1982. Sex-weight relations in blue, channel, and white catfishes: implications for brood stock selection. *Prog. Fish-Cult.* 44:105-107.
- Brusven, M.A. and C. MacPhee. 1976. The effect of river fluctuations resulting from hydroelectric peaking on selected aquatic invertebrates and fish. Final report A-035-IDA to the Office of Water Research and Technology, U.S. Dept. of Interior.
- Burbridge, R.G. 1974. Distribution, growth, selective feeding, and energy transformations of young of the year blueback herring, Alosa aestivalis (Mitchell), in the James River. *Trans. Am. Fish. Soc.* 103:297-311.
- Busbee, R.I. 1968. Piscivorous activities of the channel catfish. *Progr. Fish Cult.* 30:32-34.
- Campbell, K.P. 1979. Predation principles in large rivers: a review. in: Predator-prey systems in fisheries management, pp. 181-192. R.H. Stroup and H. Clepper, eds. Sport Fishing Institute, Washington, D.C.
- Chaston, I. 1969. Seasonal activity and feeding of brown trout (Salmo trutta) in a Dartmoor stream in relation to availability of food. *J. Fish. Res. Bd. Can.* 26:2165-2171.
- Clarke, T.A. 1978. Diel feeding patterns of 16 species of mesopelagic fishes from Hawaiian waters. *Fish. Bull.* 76:495-513.
- Corrarino, C.A. and M.A. Brusven. 1983. The effects of reduced stream discharge on insect drift and stranding of near shore insects. *Freshwater Invertebr. Biol.* 2:88-98.
- Costa, H.H. 1979. The food and feeding chronology of yellow perch (Perca flavescens) in Lake Washington. *Int. Rev. ges. Hydrobiol.* 64:783-793.
- Crisp, D.T., R.H.K. Mann and J.C. McCormack. 1978. The effects of impoundment and regulation upon the stomach contents of fish at Cow Green, Upper Teesdale. *J. Fish. Biol.* 12:287-301.

- Devaraj, K.V. 1976. On the food of channel catfish stocked in farm ponds. *Aquaculture* 7:27-32.
- Donald, D.B., R.S. Anderson and D.W. Mayhood. 1980. Correlations between brook trout growth and environmental variables for mountain lakes in Alberta. *Trans. Amer. Fish. Soc.* 109:603-610.
- Elliott, J.M. 1970. Diel changes in invertebrate drift and the food of trout, Salmo trutta L. *J. Fish. Biol.* 2:161-165.
- Elliott, J.M. 1973. The food of brown and rainbow trout (Salmo trutta and S. gairdneri) in relation to the abundance of drifting invertebrates in a mountain stream. *Oecologia* 12:329-347.
- Elrod, J.H. 1981. Food of white perch, rock bass and yellow perch in Eastern Lake Ontario. *N.Y. Fish and Game Journal* 28:191-201.
- Engel, S. 1974. Effects of formalin and freezing on length, weight, and condition factor of cisco and yellow perch. *Trans. Am. Fish. Soc.* 103:136-138.
- Environmental Resources Management (ERM). 1981a. Lower Susquehanna River oxygen dynamics study. Prepared for Maryland Power Plant Siting Program. 136 pp.
- Environmental Resources Management (ERM). 1981b. Resident fisheries study, lower Susquehanna River, Maryland. Report #PPSP-UBLS-81-5 to the State of Maryland Power Plant Siting Program.
- Fisher, S.G., and A. LaVoy. 1972. Differences in littoral fauna due to fluctuating water levels below a hydroelectric dam. *J. Fish Res. Bd. Canada* 29:1472-1476.
- Foerster, J.W. 1976. Assessment of the effect of hydroelectric water discharged from the Conowingo Dam on the spawning fish in the lower Susquehanna River. Final Report to the State of Maryland Power Plant Siting Program.
- Geaghan, J.P. and M.T. Huish. 1981. Evaluation of condition factor of fish in three North Carolina swamp streams. in: American Fisheries Society Warm Water Streams Symposium, pp. 163-167. L.A. Krumholz, ed. Lawrence, Kansas: Allen Press.
- Gibson, R.J. and D. Galbraith. 1975. The relationships between invertebrate drift and salmonid populations in the Matanek River, Quebec, below a lake. *Trans. Amer. Fish. Soc.* 104:529-535.

- Gilmurray, M.C. and G.R. Daborn. 1981. Feeding relations of the Atlantic silverside Menidia menidia in the Minas Basin, Bay of Fundy. Mar. Ecol. Prog. Ser. 6:231-235.
- Gislason, J.C. 1985. Aquatic insect abundance in a regulated stream under fluctuating and stable diel flow patterns. N. Amer. J. Fish. Mgmt. 5:39-46.
- Griffith, J.S. 1974. Utilization of invertebrate drift by brook trout (Salvelinus fontinalis) and cutthroat trout (Salmo clarki) in small streams in Idaho. Trans. Amer. Fish. Soc. 103:440-447.
- Haddock, J.D. 1977. The effect of stream current velocity on the habitat preference of a net-spinning caddisfly larva, Hydropsyche oslari Banks. Pan-Pac. Entomol. 53:169-174.
- Hanson, J.M. and W.C. Leggett. 1985. Experimental and field evidence for inter- and intraspecific competition in two freshwater fishes. Can. J. Fish. Aquat. Sci. 42:281-286.
- Hauer, F.R. and J.A. Stanford. 1982. Ecological responses of hydropsychid caddisflies to stream regulation. Can. J. Fish. Aquat. Sci. 39:1235-1242.
- Henricson, J., and K. Muller. 1979. Stream regulation in Sweden with some examples from central Europe. in: The Ecology of Regulated Streams, pp. 183-199. J.V. Ward and J.A. Stanford, eds. New York: Plenum Press.
- Hildebrand, S.G. 1974. The relation of drift to benthos density and food level in an artificial stream. Limnol. Oceanogr. 19:951-957.
- Hines, R. 1981. The ecological significance of a stunted white perch population in an eutrophic Maine pond. M.S. Thesis University of Maine. Orono, Maine.
- Hooper, F.F. and D.R. Ottey. 1982. Prediction of effects of daily flow fluctuations on stream biota. Report #OWRTA-113-MICH to Office of Water Research and Technology.
- Hughes, D.A. 1970. Some factors affecting drift and upstream movements of Gammarus pulex. Ecology 51:301-5.
- Hutchinson, G.E. 1967. A Treatise on Limnology. Vol. II. Introduction to Lake Biology and the Limnoplankton. New York: John Wiley and Sons, Inc. 1115 pp.
- Hynes, H.B.N. 1970. The ecology of running waters. University of Toronto Press.

- Jackson, D.R., and G.J. Lazorcheck. 1978. Instream flow needs study, Susquehanna River, vicinity of Conowingo Dam. Susquehanna River Basin Commission. 54 pp.
- Janicki, A., and R. Ross. 1982. Benthic invertebrate communities in the fluctuating riverine habitat below Conowingo Dam. Prepared for Maryland Department of Natural Resources, Power Plant Siting Program, by Martin Marietta Environmental Center. Report #UBLS-82-1.
- Jearld, A., and B.E. Brown. 1971. Food of the channel catfish (Ictalurus punctatus) in a southern great plains reservoir. Amer. Midl. Naturalist 86:110-115.
- Jenkins, T.M., C.R. Feldmeth and G.V. Elliott. 1970. Feeding of rainbow trout (Salmo gairdneri) in relation to abundance of drifting invertebrates in a mountain stream. J. Fish. Res. Bd. Can. 27: 2356-2361.
- Johnson, J.H. and E.Z. Johnson. 1982. Diel foraging in relation to available prey in an Adirondack mountain stream fish community. Hydrobiologia 96:97-104.
- Jonasson, P.M. 1972. Ecology and production of the profundal benthos in relation to phytoplankton in Lake Esrom. Oikos, Suppl. 148 pp.
- Jorgensen, S.E. 1979. Handbook of environmental data and ecological parameters. Copenhagen: Int. Society for Ecological Modeling. 1162 pp.
- Keast, A. 1977. Diet overlaps and feeding relationships between the year classes in the yellow perch (Perca flavescens). Env. Biol. Fish. 2:53-70.
- Keast, A., and L. Welsh. 1968. Daily feeding periodicities, food uptake rates, and dietary changes with hour of day in some lake fishes. J. Fish. Res. Bd. Canada. 25:1133-1144.
- Kennedy, C.R. 1969. Tubificid oligochaetes as food of dace. J. Fish Biol. 1:11-15.
- LeCren, E.D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). J. Anim. Ecol. 20:201-219.
- Mackie, G.L., and R.C. Bailey. 1981. An inexpensive bottom sampler. J. Freshwater Ecol. 1:61-69.
- Mancini, E.R., M. Busdosh and D.B. Steele. 1979. Utilization of autochthonous macroinvertebrate drift by a pool fish community in a woodland stream. Hydrobiologia 62:249-256.

- Marsh, P.C. 1981. Food of channel catfish in the Coachella Canal, California. J. Ariz.-Nev. Acad. Sci. 16:91-95.
- Mason, J.C. 1976. Response of underyearling coho salmon to supplemental feeding in a natural stream. J. Wildl. Mgt. 40:775-788.
- Mathur, D. 1971. Food habits and feeding chronology of channel catfish Ictalurus punctatus (Rafinesque) in Conowingo Reservoir. Proc. 24th Annual Conf. Southeastern Assoc. Game and Fish Comm. 377-386.
- McClain, J.R. 1976. The food habits of brook trout in relation to the abundance of diel drift invertebrates in the Little Colorado River. M.S. Thesis. Univ. of Arizona. 37 pp.
- McMahon, T.E. and J.W. Terrell. 1982. Habitat suitability index models: channel catfish. U.S. Fish and Wildlife Service report FWS/OBS-82/10.2.
- Merritt, R.W., and K.W. Cummins. 1978. An Introduction to the Aquatic Insects of North America. Dubuque, Iowa: Kendall/Hunt Publishing Co. 441 pp.
- Miller, L.W. 1963. Growth, reproduction and food habits of the white perch, Roccus americanus (Gmelin), in the Delaware River estuary. M.S. Thesis, University of Delaware. 62pp.
- Mills, E.L. and J.L. Forney. 1981. Energetics, food consumption, and growth of young yellow perch in Oneida Lake, New York. Trans. Amer. Fish Soc. 110:479-488.
- Minshall, G.W. and P.V. Winger. 1968. The effect of reduction in stream flow on invertebrate drift. Ecology 49:580-582.
- Nakashima, B.S., and W.C. Leggett. 1978. Daily ration of yellow perch (Perca flavescens) from Lake Mephremagog, Quebec-Vermont, with a comparison of methods for in situ determinations. J. Fish. Res. Bd. Can. 35:1597-1603.
- Newman, R.M. and T.F. Waters. 1984. Size selective predation on Gammarus pseudolimnaeus by trout and sculpins. Ecology 65:1535-1545.
- Noble, R.L. 1975. Growth of young yellow perch (Perca flavescens) in relation to zooplankton populations. Trans. Amer. Fish. Soc. 104:731-741.
- Norman, C. 1981. Renewable power sparks financial interest. Science 212:1479-1481.

- Orlova, E.L. and O.A. Popova. 1976. The feeding of the predatory fish, the sheatfish Silurus glanis, and the pike, Esox lucius, in the Volga delta following regulation of the discharge of the river. J. Ichthyol. 16:75-87.
- Palmer, T. 1983. What price "free" energy? Sierra July/Aug. 1983:40-47.
- Pavol, K.W. and R.M. Davis. 1982. Life history and management of the smallmouth bass in the Susquehanna River below Conowingo Dam. Report F-29-R to the State of Maryland Wildlife Administration.
- Pearson, W.D. and D.R. Franklin. 1968. Some factors affecting drift rates of Baetis and Simuliidae in a large river. Ecology 49:75-81.
- Pennak, R.W. 1978. Freshwater Invertebrates of the United States. 2nd Ed. New York: Wiley-Interscience. 803 pp.
- Refstie, T. 1977. Effect of density on growth and survival of rainbow trout. Aquaculture 11:329-334.
- Richkus, W.A. 1983. Testimony before the Federal Energy Regulatory Commission hearings on Conowingo Dam, September 23, 1983.
- Ringler, N.H., and J.H. Johnson. 1982. Diel composition and diel feeding periodicity of some fishes in the St. Lawrence River. N.Y. Fish and Game Journal 29:65-74.
- Robbins, T.W., E.T. Euston, D.A. Wahl, and D. Mathur. 1974. Studies of the food habits of the common fishes and the abundance of zooplankton and benthos in Conowingo Pond in relationship to water temperature. Report to Philadelphia Electric Company by Ichthyological Associates, Inc. 49 pp.
- Serebrov, L.I. 1973. Effects of current on the intensity of feeding in certain fish. Hydrobiol. J. 9:68-70.
- Shenker, J.M. and D.J. Hepner. 1980. Distribution and abundance of demersal fish eggs in the Susquehanna River below the Conowingo Dam, Maryland. Report to the State of Maryland Power Plant Siting Program. Prepared by the Philadelphia Academy of Natural Sciences.
- Simco, B.A. and F.B. Cross. 1966. Factors affecting growth and production of channel catfish, Ictalurus punctatus. Publ. Univ. Kans. Mus. Nat. Hist. 17:191-256.
- Slaney, P.A. and T.G. Northcote. 1974. Effects of prey abundance on density and territorial behavior of young rainbow trout (Salmo gairdneri) in laboratory stream channels. J. Fish. Res. Bd. Can. 31:1201-1209.

- Smith, M.W. 1947. Food of killifish and white perch in relation to supply. J. Fish. Res. Bd. Can. 7:22-34.
- Stanford, J.A. and J.V. Ward. 1979. Dammed Rivers of the World: Symposium Rationale. In: The Ecology of Regulated Streams. J.V. Ward and J.A. Stanford, Eds. New York: Plenum Press. 398 pp.
- Stobo, W.T. 1972. Effects of formalin on the length and weight of yellow perch. Trans. Amer. Fish. Soc. 101:362-364.
- Swingle, H.S. 1954. Fish populations in Alabama rivers and impoundments. Trans. Amer. Fish. Soc. 83:47-57.
- Townsend, C.R. and A.G. Hildrew. 1976. Field experiments on the drifting, colonization and continuous redistribution of stream benthos. J. Anim. Ecol. 55:759-772.
- Trotzky, H.M. and R.W. Gregory. 1974. The effects of water flow manipulation below a hydroelectric power dam on the bottom fauna of the upper Kennebec River, Maine. Trans. Am. Fish. Soc. 103:318-324.
- Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The River Continuum Concept. Can. J. Fish. Aquat. Sci. 37:130-137.
- Walburg, C.H., G.L. Kaiser and P.L. Hudson. 1971. Lewis and Clark Lake Tailwater biota and some relations of the tailwater and reservoir fish populations. Amer. Fish. Soc. Spec. Publ. #8:449-467.
- Ware, F.J. 1967. The food habits of channel catfish in South Florida. Proc. 20th Ann. Conf. Southeastern Assoc. Game and Fish Comm. 283-287pp.
- Weatherley, A.H. 1972. Growth and ecology of fish populations. New York: Academic Press.
- Webster, D.A. 1942. Food progression in young white perch, Morone americana (Gmelin) from Bantam Lake, Connecticut. Trans. Amer. Fish. Soc. 72:136-144.
- Weisberg, S.B., R. Whalen and V.A. Lotrich. 1981. Tidal and diurnal influence on food consumption of a salt marsh killifish Fundulus heteroclitus. Mar. Biol. 61:243-246.
- Weisberg, S.B. and V.A. Lotrich. In press. Food limitation of a Delaware salt marsh population of the mummichog, Fundulus heteroclitus (L.) Oecologia.

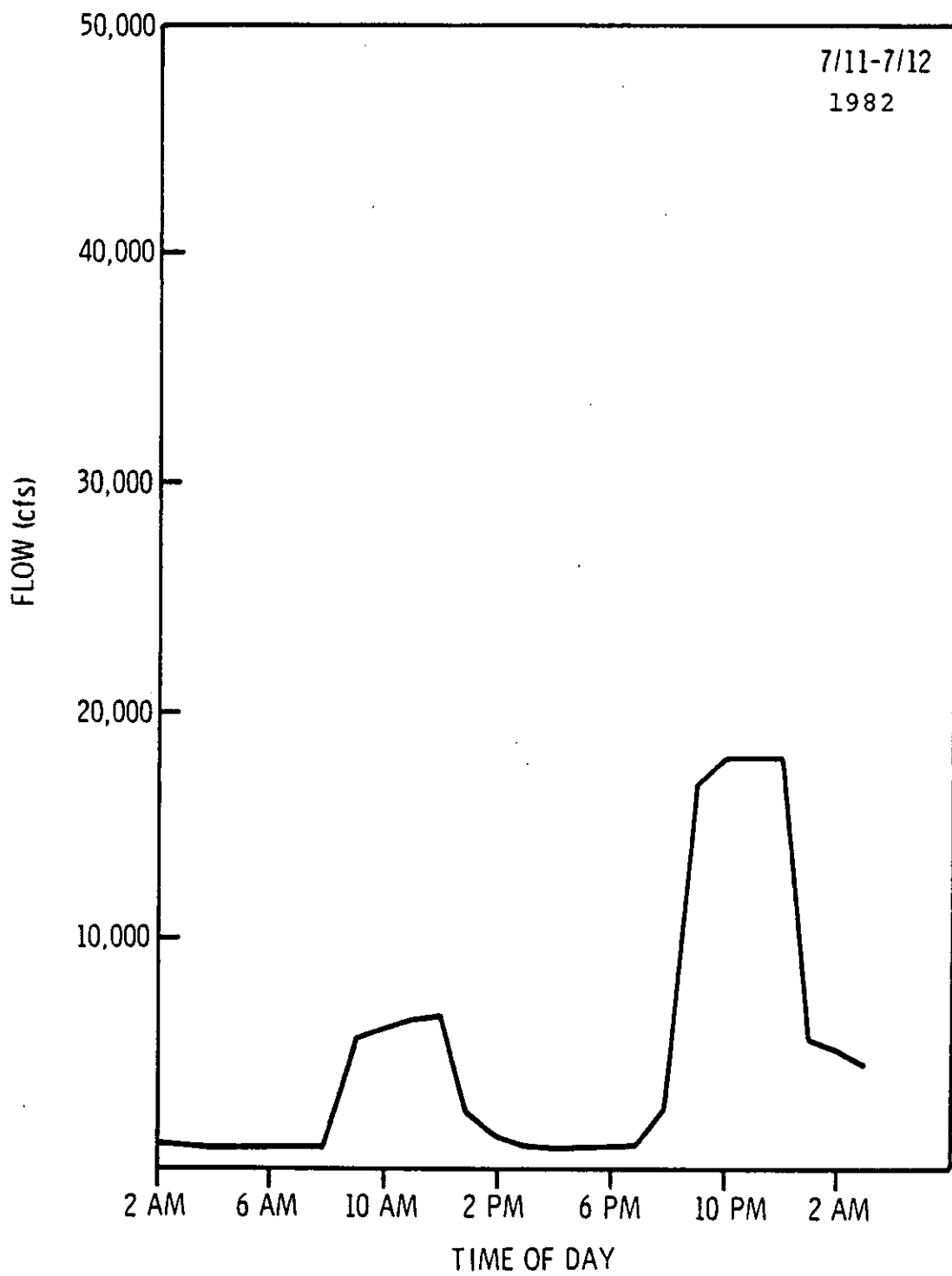
Williams, R.D. and R.N. Winget. 1979. Macroinvertebrate response to flow manipulation in the Strawberry River, Utah (U.S.A.). in: The Ecology of Regulated Streams, pp. 365-376. J.V. Ward and J.A. Standord, eds. New York: Plenum Press.

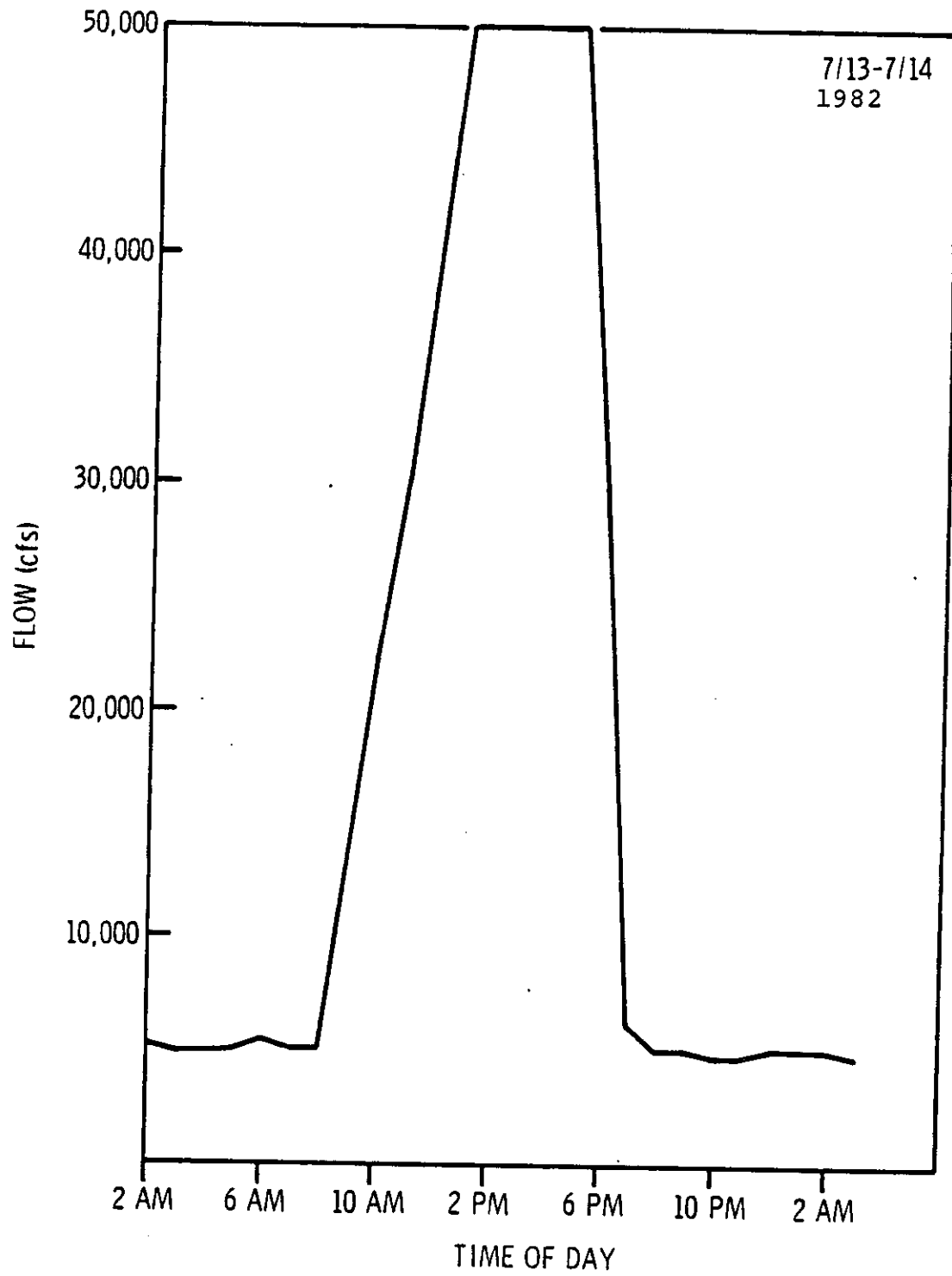


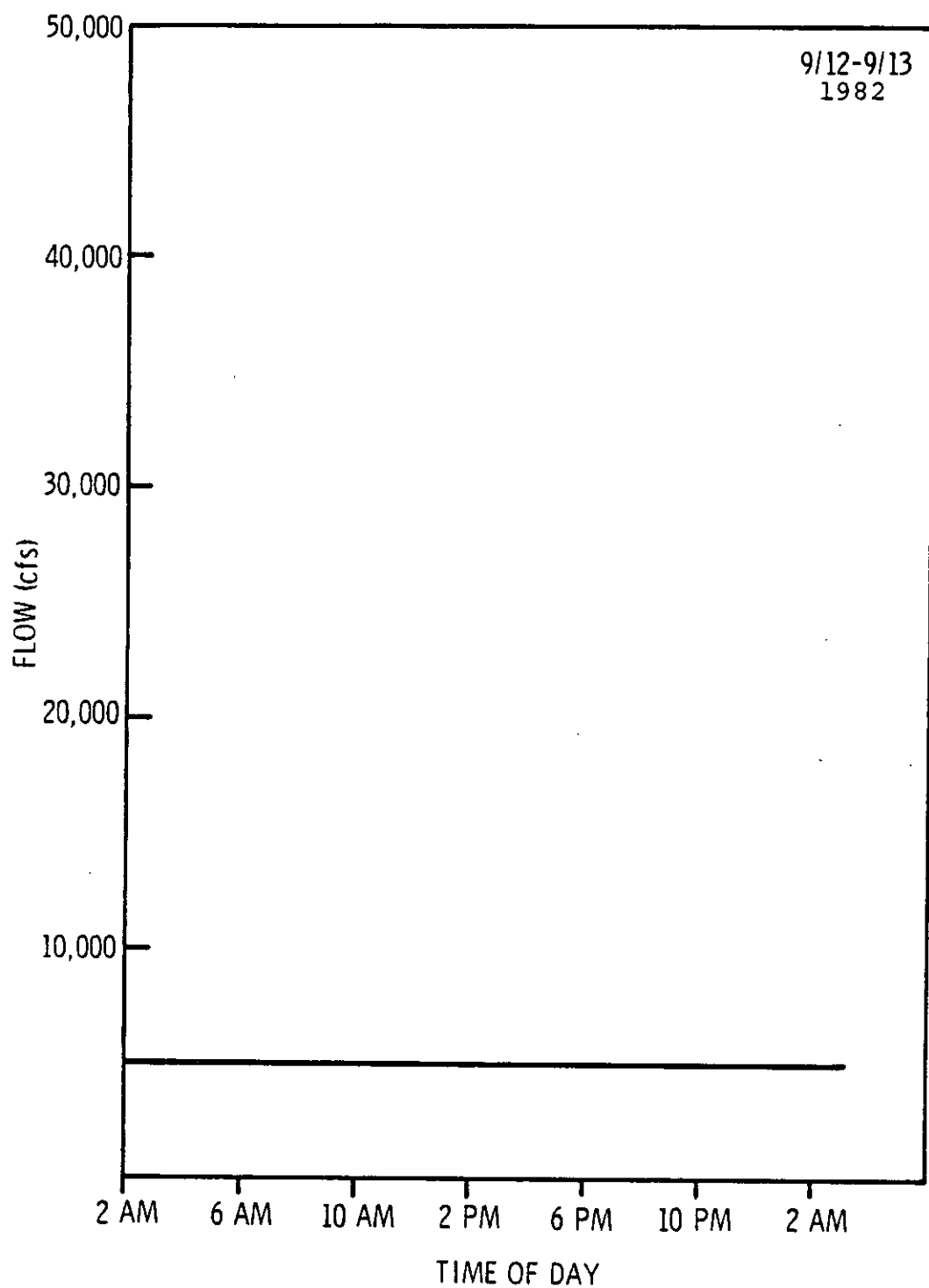
APPENDIX A

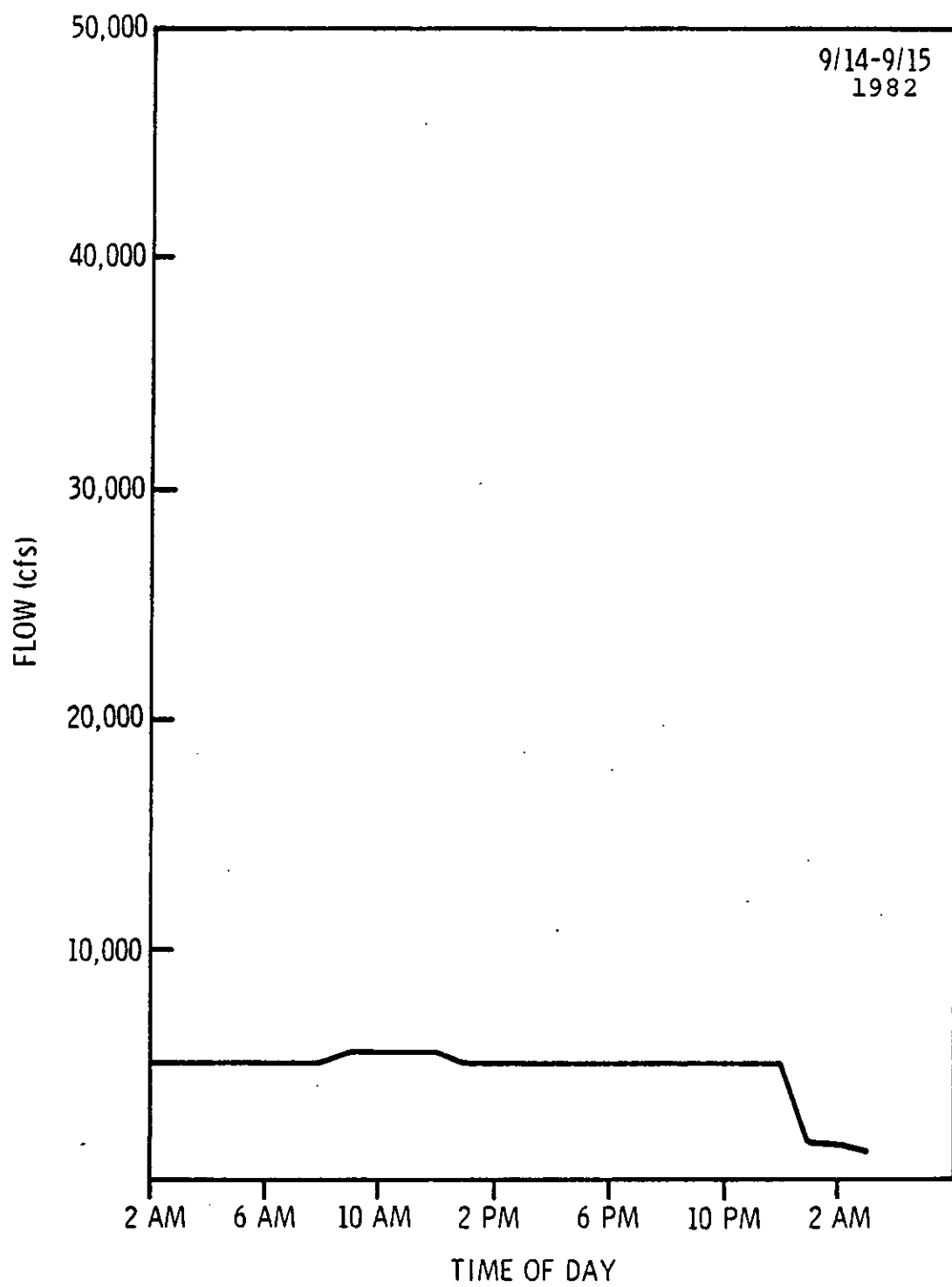
A record of flow conditions on each  
day in 1982 and 1983 on which  
fish were sampled

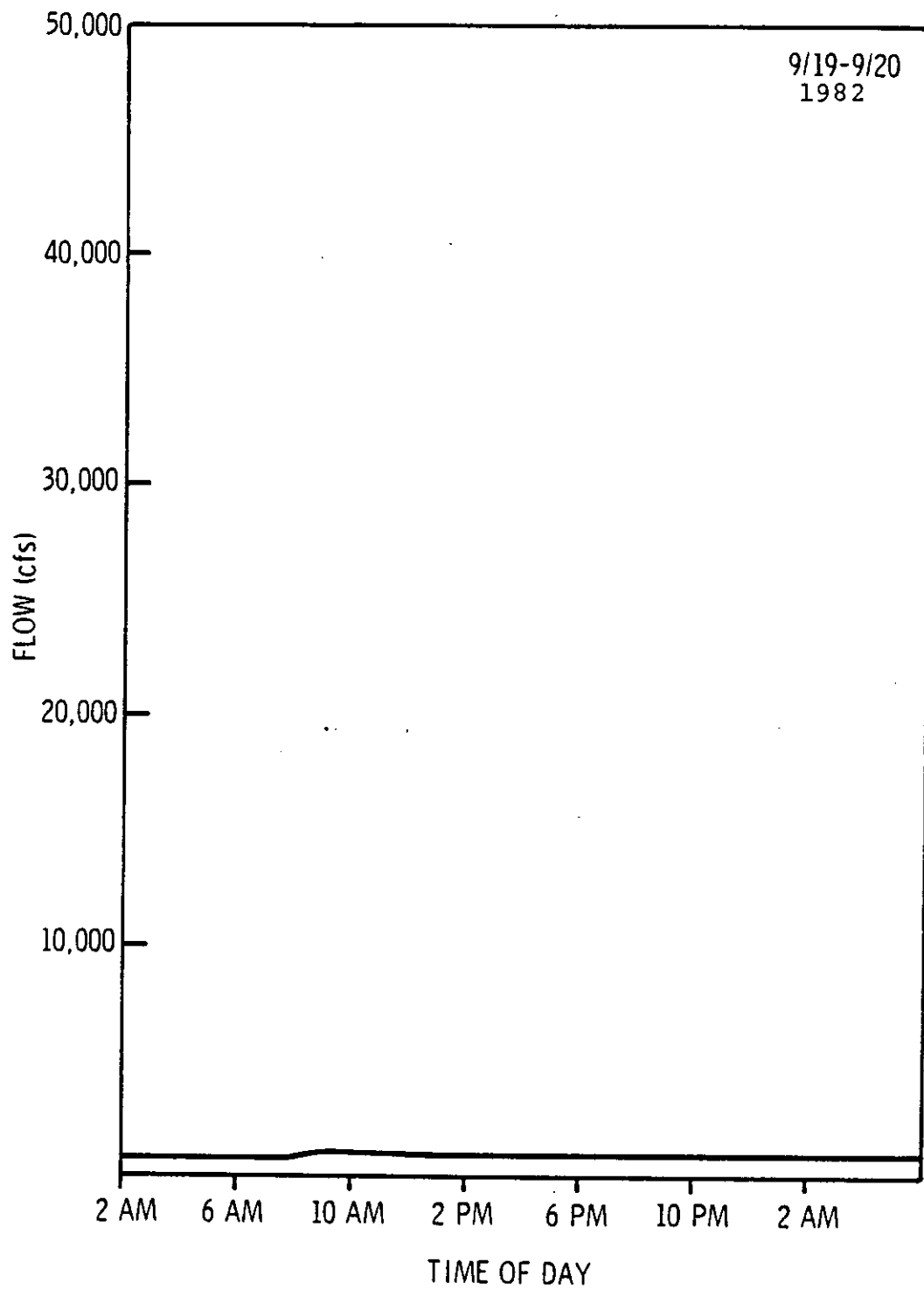


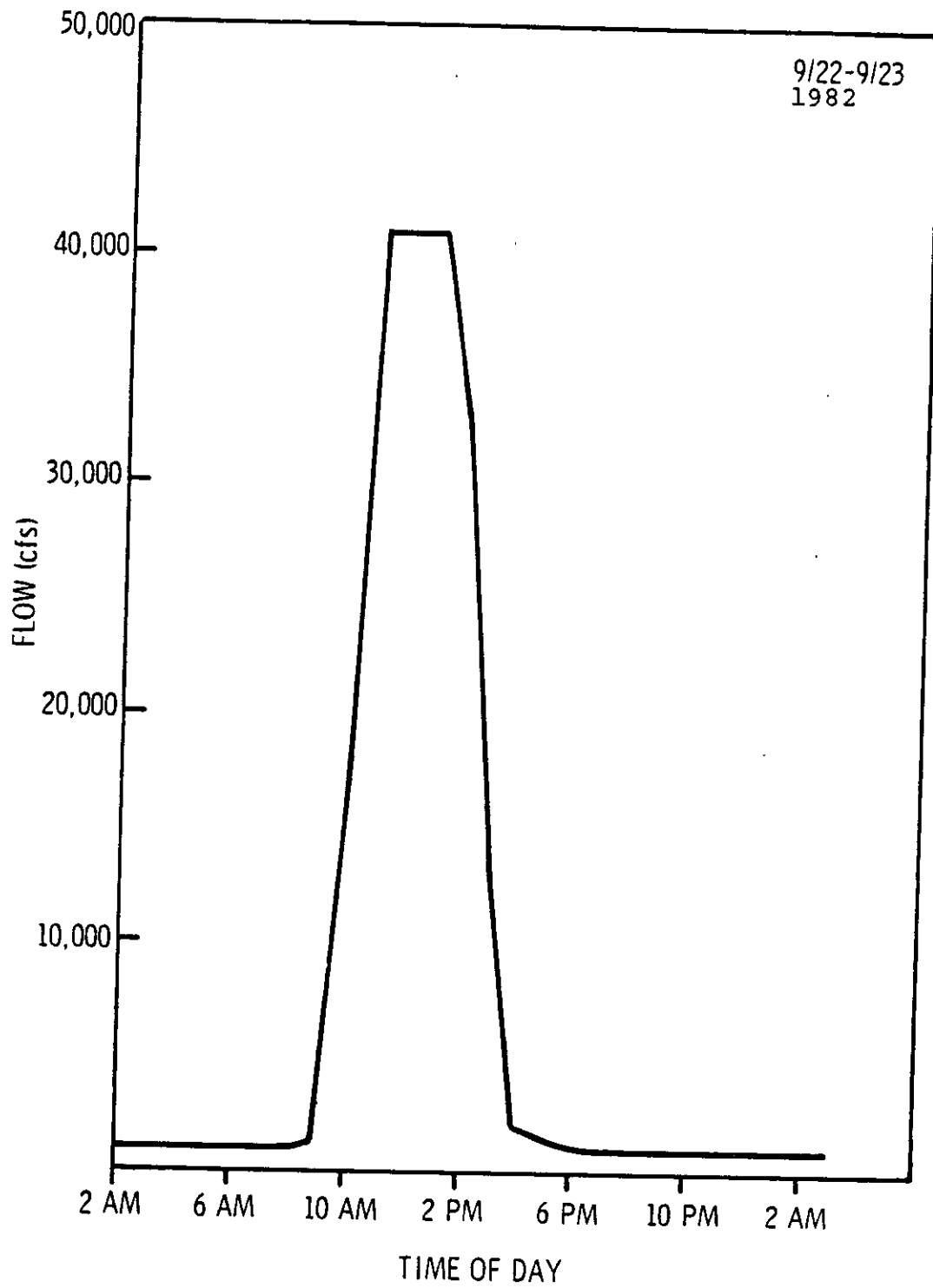


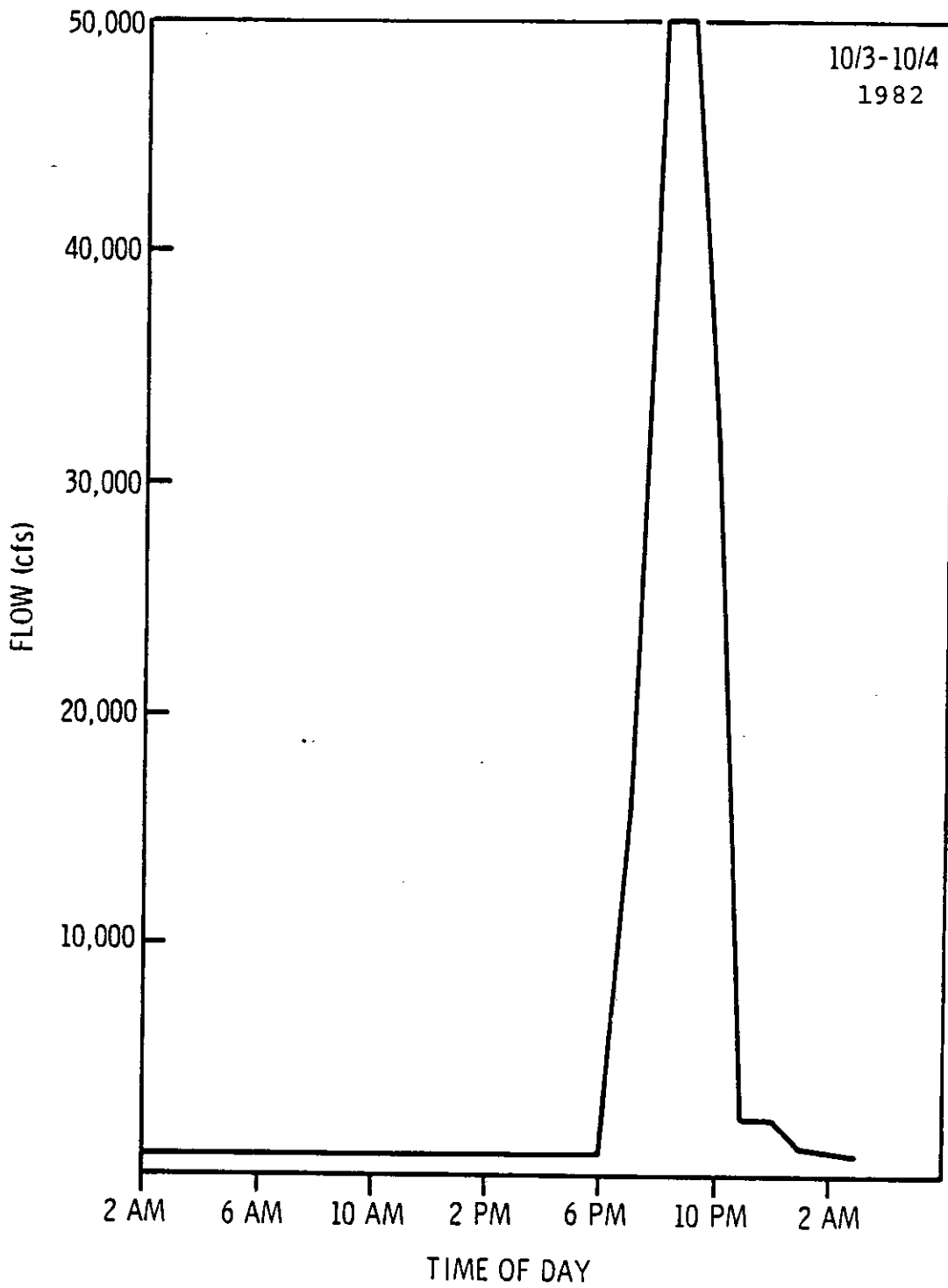


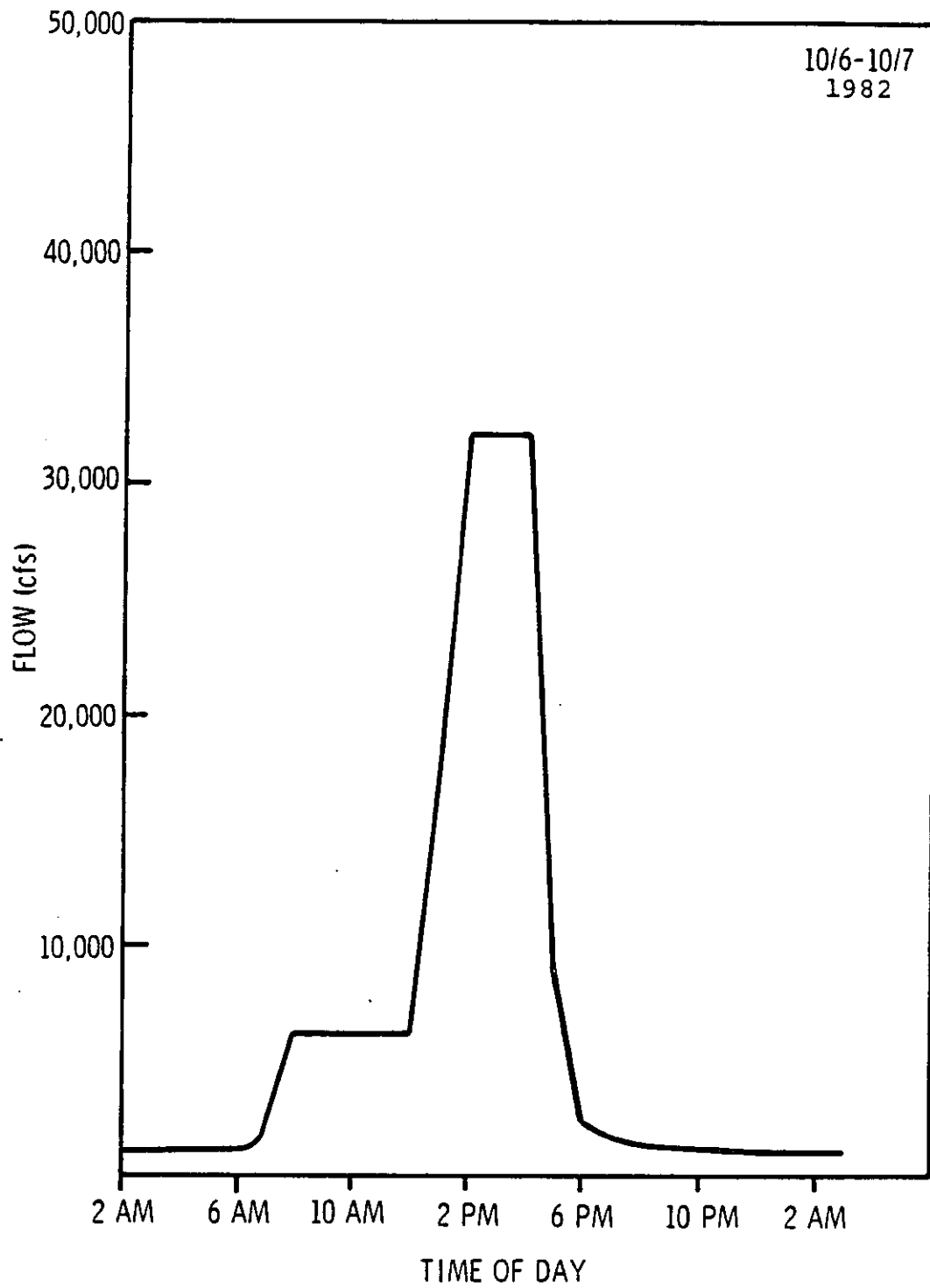


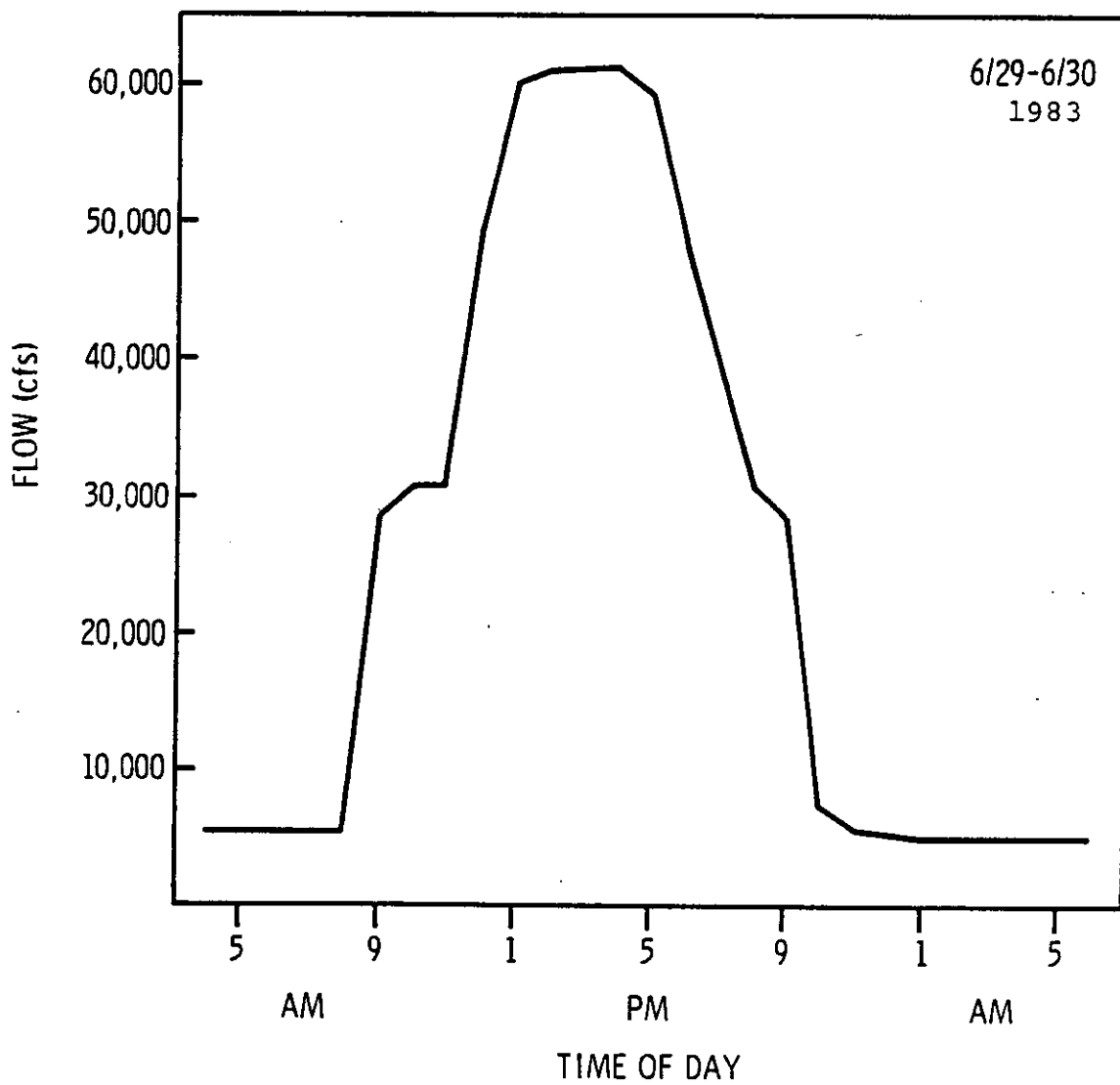


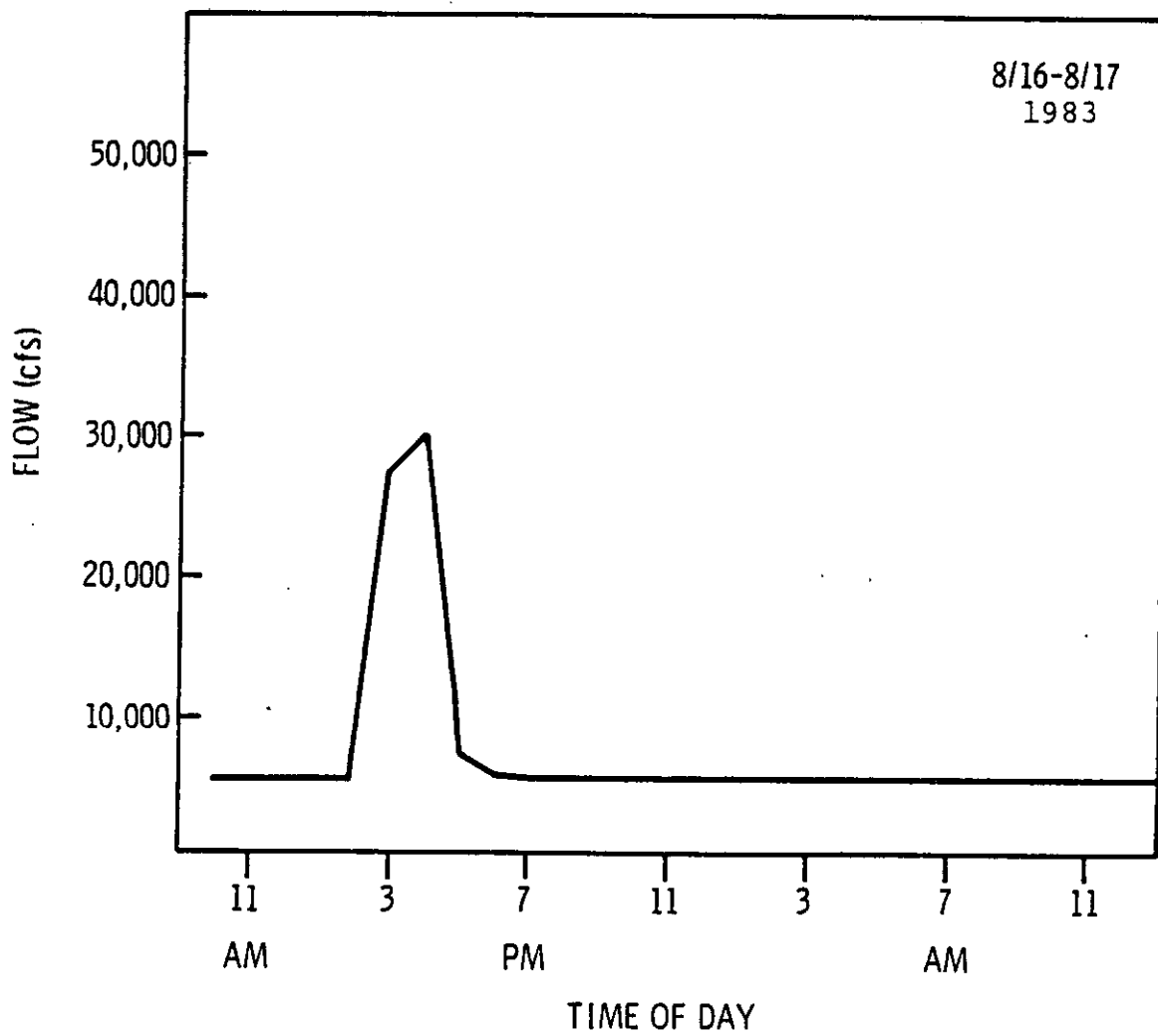


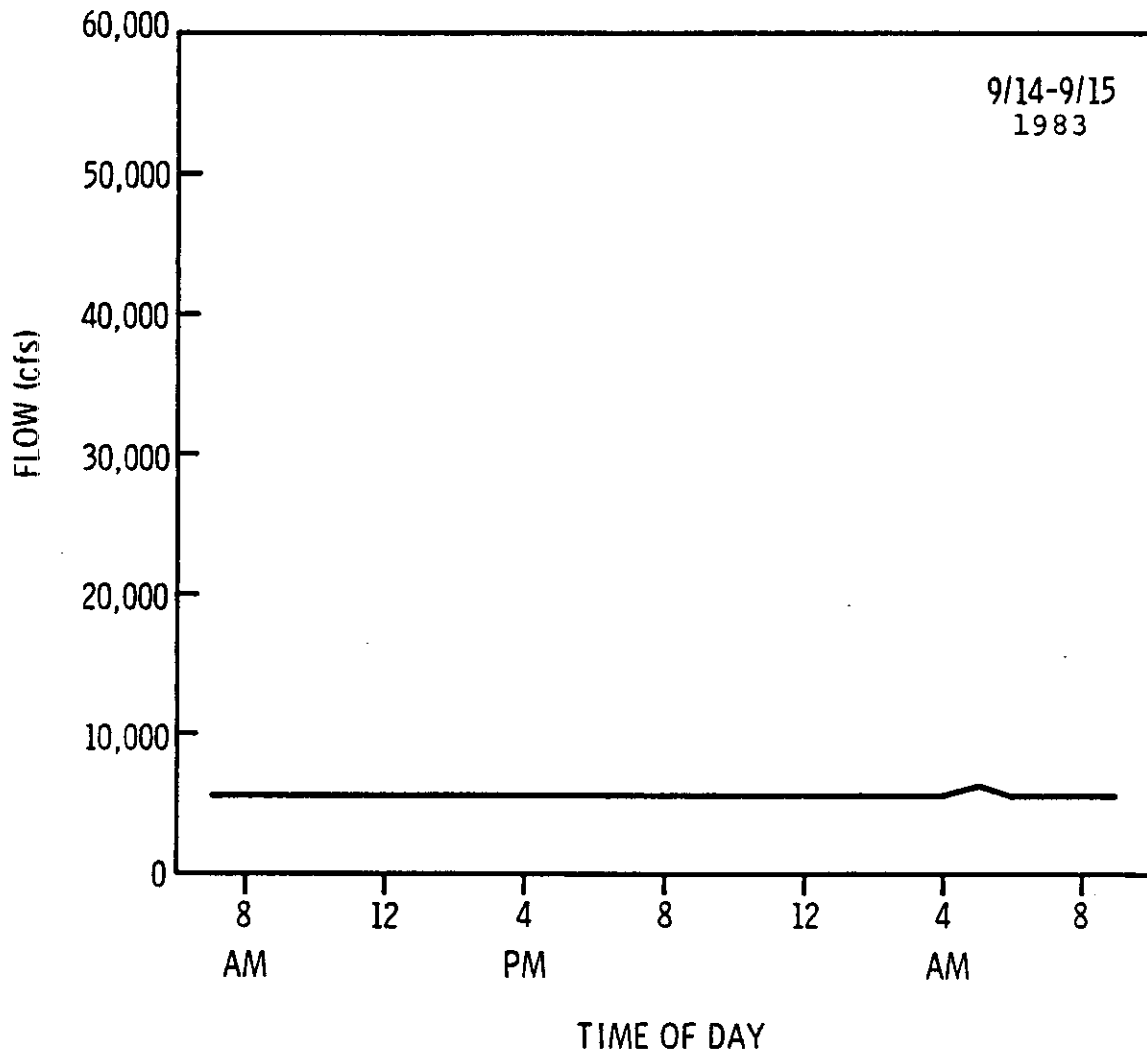


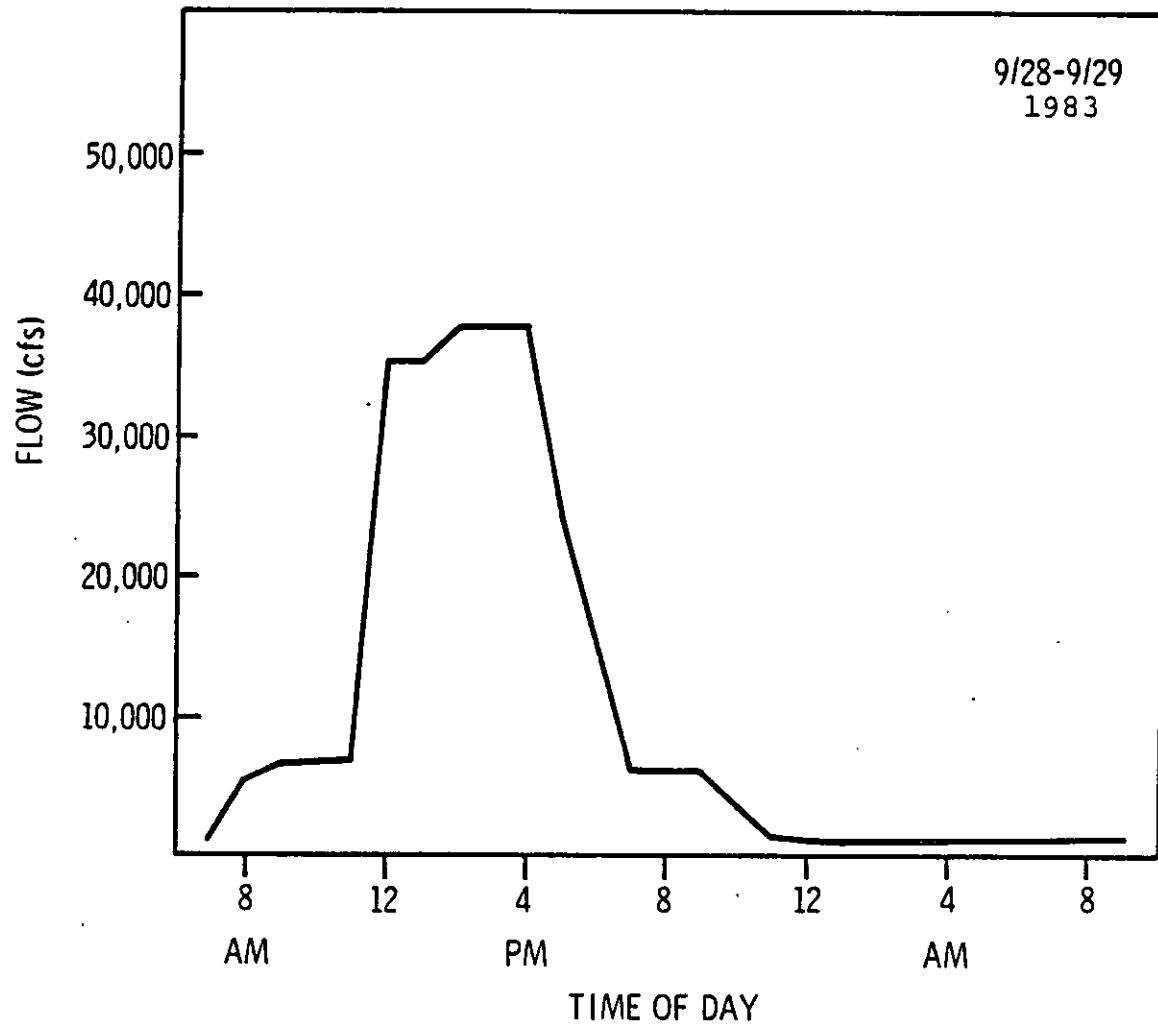


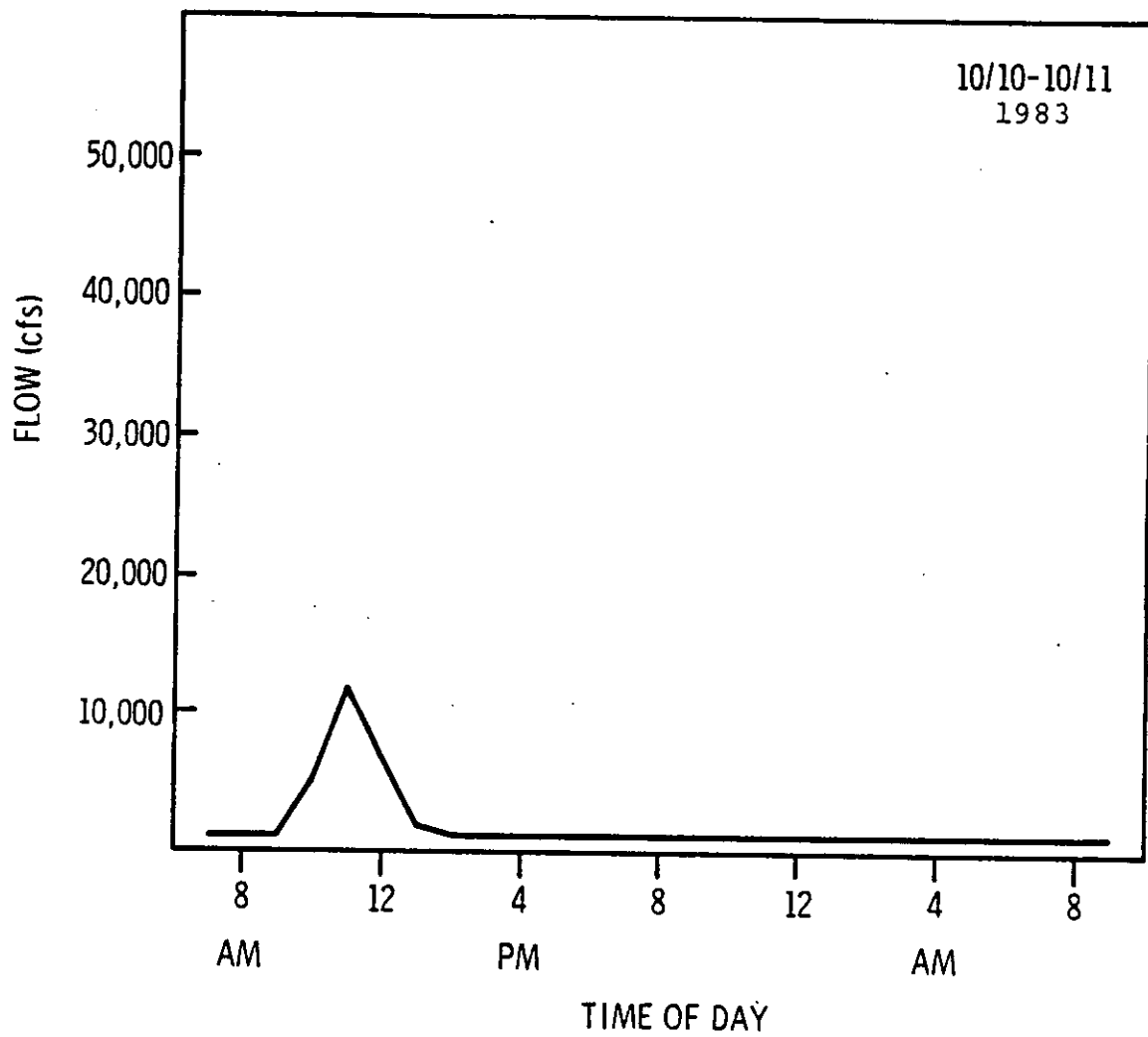














APPENDIX B

DIETS OF INCIDENTALLY COLLECTED  
FISH SPECIES



Table B-1. Diet of green sunfish (Lepomis cyanellus) in the Susquehanna River (N = 15)

Prey	Mean Number Per Fish	Frequency in Diet (%)	Biomass Contribution (% of Total Biomass)
Chironomid larvae	24.1	40.0	24.1
<u>Cyrnellus fraternus</u> larvae	12.6	33.3	43.7
Other Trichoptera	1.4	13.3	9.0
<u>Cheumatopsyche</u> larvae	1.3	26.7	17.8
Chironomid pupae	0.7	26.7	0.7
<u>Gammarus fasciatus</u>	0.3	13.3	2.3
Unidentified insects	0.1	13.3	0.9
Hydroptilidae larvae	0.1	6.7	0.9
Isopoda	0.1	6.7	0.3
<u>Ceraclea</u>	0.1	6.7	0.2
Decapoda	0.1	6.7	0.2

Proportion of fish  
with empty stomachs = 26.7%

Table B-2. Diet of bluegill (Lepomis macrochirus) in the Susquehanna River (N = 20)

Prey	Mean Number Per Fish	Frequency in Diet (%)	Biomass Contribution (% of Total Biomass)
Chironomid larvae	72.6	60.0	33.0
Chironomid pupae	10.4	55.0	5.0
<u>Cheumatopsyche</u> larvae	7.0	25.0	44.6
Other trichoptera	3.6	25.0	10.5
<u>Chaoborus</u>	0.8	5.0	1.5
<u>Cheumatopsyche</u> adults	0.6	5.0	0.8
<u>Gammarus fasciatus</u>	0.4	30.0	1.4
Cladocerans	0.4	15.0	0.1
Hydroptilidae larvae	0.3	5.0	0.9
<u>Cyrnellus fraternus</u> larvae	0.2	10.0	0.4
Copepods	0.2	5.0	0.0
Coleoptera	0.1	10.0	0.3
<u>Cheumatopsyche</u> pupae	0.1	5.0	0.7
<u>Ferrissia</u>	0.1	5.0	0.6
Hymenoptera	0.1	5.0	0.1
Tabanidae	0.1	5.0	0.1
Oligochaetes	0.1	5.0	0.0

Proportion of fish  
with empty stomachs = 30.0%

Table B-3. Diet of white catfish (Ictalurus catus) in the Susquehanna River (N = 22)

Prey	Mean Number Per Fish	Frequency in Diet (%)	Biomass Contribution (% of Total Biomass)
Chironomid larvae	17.7	63.6	15.6
Copepods	14.2	18.2	0.1
<u>Gammarus fasciatus</u>	3.4	31.8	20.7
<u>Cheumatopsyche</u> larvae	3.1	22.7	38.1
Cladocerans	2.2	27.3	0.5
<u>Cyrtellus fraternus</u> larvae	0.9	27.3	2.8
Chironomid pupae	0.6	13.6	0.5
<u>Cheumatopsyche</u> pupae	0.4	4.5	9.6
Trichoptera	0.4	4.5	2.0
Oligochaetes	0.3	9.1	0.6
Sphaeriidae	0.2	9.1	5.1
Hydroptilidae larvae	0.2	4.5	1.1
Ephemeroptera	0.2	4.5	1.0
Physidae	0.1	4.5	1.0
Ostracoda	<0.1	4.5	0.1

Proportion of fish  
with empty stomachs = 18.2%

Table B-4. Diet of brown bullhead (Ictalurus nebulosus)  
the Susquehanna River (N = 11)

Prey	Mean Number Per Fish	Frequency in Diet (%)	Biomass Contribution (% of Total Biomass)
<u>Gammarus fasciatus</u>	5.5	45.5	51.8
Chironomid larvae	3.3	54.5	4.4
<u>Cyrtellus fraternus</u> larvae	2.3	36.4	10.5
Sphaeriidae	0.6	36.4	21.8
Chironomid pupae	0.2	18.2	0.3
Hydrobiidae	0.1	9.1	3.1
Pleuroceridae	0.1	9.1	3.1
Unidentified gastropods	0.1	9.1	3.1
<u>Cheumatopsyche</u> larvae	0.1	9.1	1.7
Oligochaetes	0.1	9.1	0.2

Proportion of fish  
with empty stomachs = 45.5%

Table B-5. Diet of pumpkinseed (Lepomis gibbosus) in the Susquehanna River (N = 37)

Prey	Mean Number Per Fish	Frequency in Diet (%)	Biomass Contribution (% of Total Biomass)
Chironomid larvae	39.9	45.9	22.6
<u>Gammarus fasciatus</u>	5.9	24.3	23.5
<u>Cheumatopsyche</u> larvae	5.1	21.6	40.1
Chironomid pupae	1.2	27.0	0.7
<u>Cyrnellus fraternus</u> larvae	1.2	18.9	2.3
Hymenoptera	0.7	2.7	2.6
Hydroptilidae larvae	0.3	10.8	1.3
Sphaeriidae	0.3	13.5	4.3
<u>Chaoborus</u>	0.2	5.4	0.4
<u>Ferrissia</u>	0.1	5.4	1.2
Coleoptera	0.1	5.4	0.3
Trichoptera	0.1	5.4	0.3
Cladocerans	0.1	2.7	<0.1
Planorbidae	<0.1	2.7	0.4
<u>Ceraclea</u>	<0.1	2.7	<0.1
Oligochaetes	<0.1	2.7	<0.1

Proportion of fish  
with empty stomachs = 54.1%



TR 85-6

#4299



